



# ADVANCED INSTRUMENTATION *and* INSPECTION

**FOR DEEPWATER OIL AND GAS**

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# FAILURES TO **MONITOR AND PREDICT**

- Detect early warning signs
- Automate monitoring of critical systems
- Give critical data to key decision makers



**Deepwater Horizon**  
2010

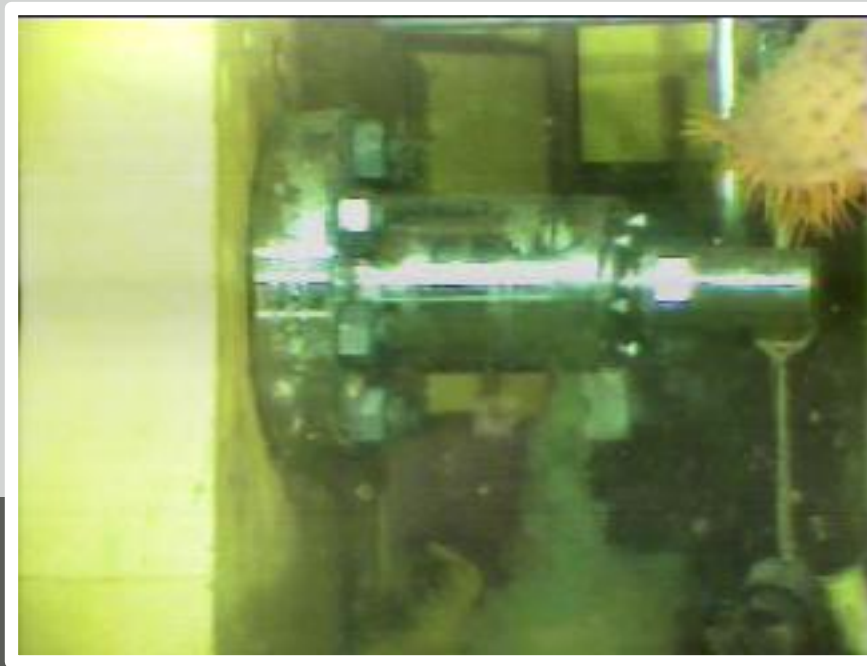


**Thunder Horse**  
2005



**Texas City Refinery**  
2005

# SMALL LEAKS IN SUBSEA FIELDS



# THE NEED FOR **BETTER SUBSEA INSTRUMENTATION**

## Prevent Undesired Events from Happening

- Detect warning signs early
- Prevent potential accidents from occurring
- Improve system operations
- Automate monitoring of critical systems
- Track pressure, temperature, strain and flow
- Give critical data to key decision makers
- Eliminate production downtime
- Prevent asset damage and pipeline leaks
- Reduce safety and environmental risks

# FROM AEROSPACE TO SUBSEA

## Clear Gulf Study

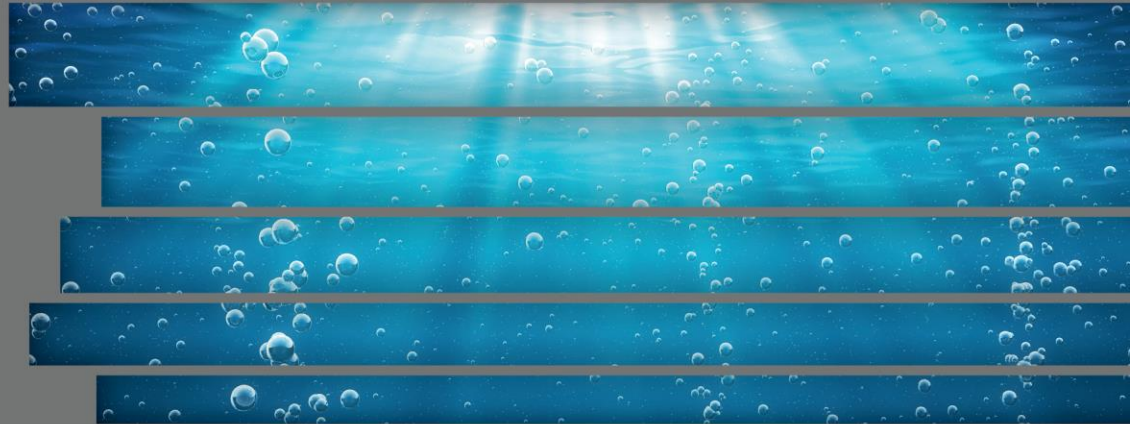


# ABOUT **CLEAR GULF STUDY**

Prevention of Unwanted Events, Rather than Reaction

## ADVANCED INSTRUMENTATION FOR:

- Subsea fields
- Pipelines and risers
- LNG facilities



## **CLEAR GULF FOCUS AREAS:**

- |                               |                                 |                          |
|-------------------------------|---------------------------------|--------------------------|
| • Risers and Flowlines        | • Leak Detection                | • Arctic Monitoring      |
| • Flow Assurance              | • Smart Fields (Intelli-Fields) | • Service Life Extension |
| • Subsea Equipment Monitoring | • Downhole Monitoring           |                          |
| • Miniature Subsea Robotics   | • Mooring Line Monitoring       |                          |

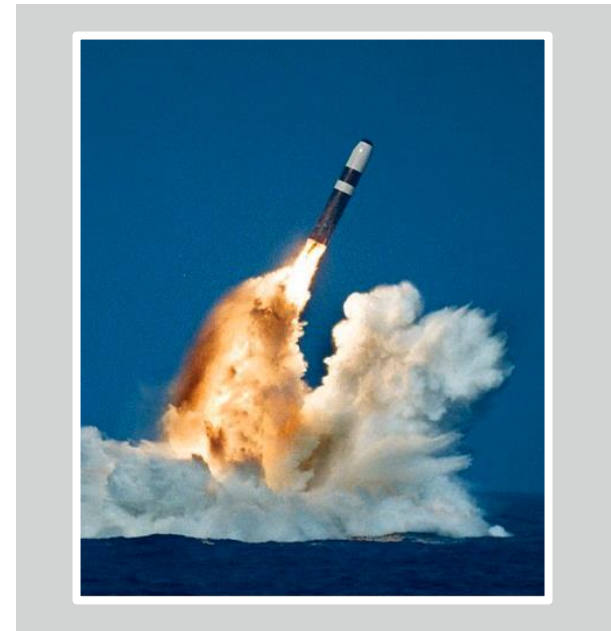
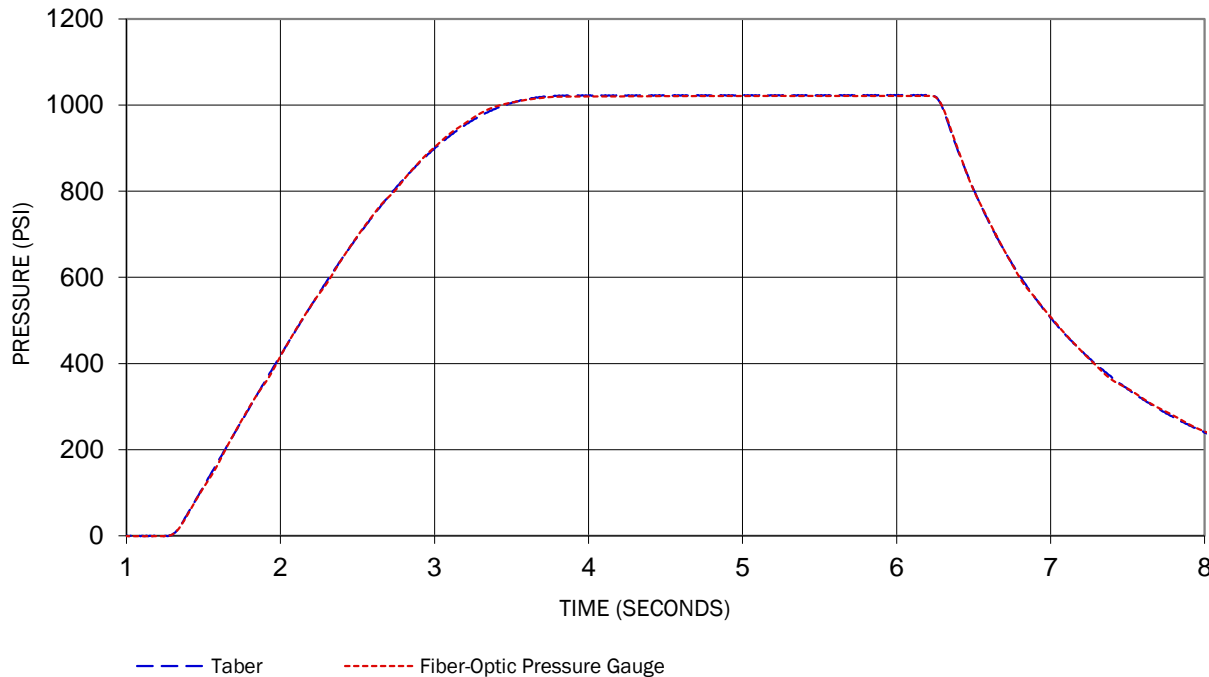
# ADVANTAGES OF **CLEAR GULF**

## Prevention of Anomalies

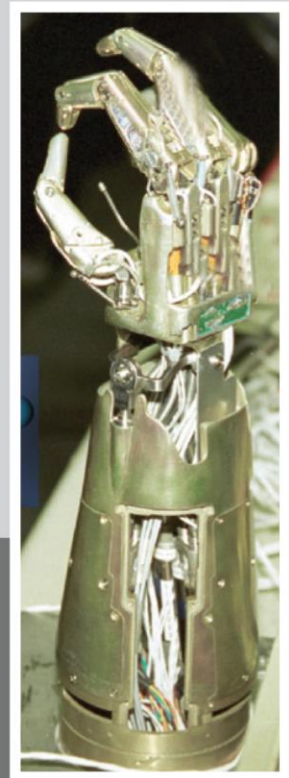
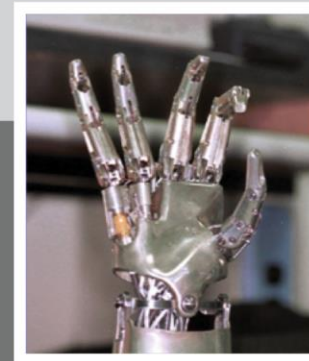
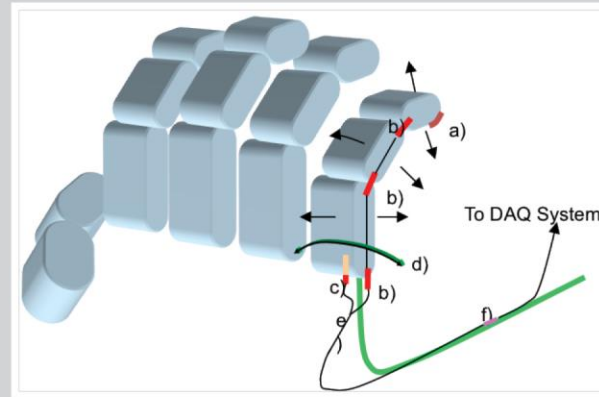
- Improve performance
- Reduce risk – environmental and safety
- Involvement in advanced technology research for oil and gas
- NASA collaboration
- Outside research institutions involvement, i.e. multiple universities
- Industry “subject-matter experts” interface
- Participation on “Technical Steering Committee”
- Access to leading-edge technology
- Significant cost benefit — pooling funding resources
- Acts as an R&D department for oil and gas companies
  - Supplements R&D efforts at large companies
  - Provides new R&D departments for smaller, independent companies
- Participate in annual meeting with U.S. Congress

# FIBER-OPTIC SENSOR ROCKET MOTOR TEST

## Fiber-Optic Pressure Gauge Validation

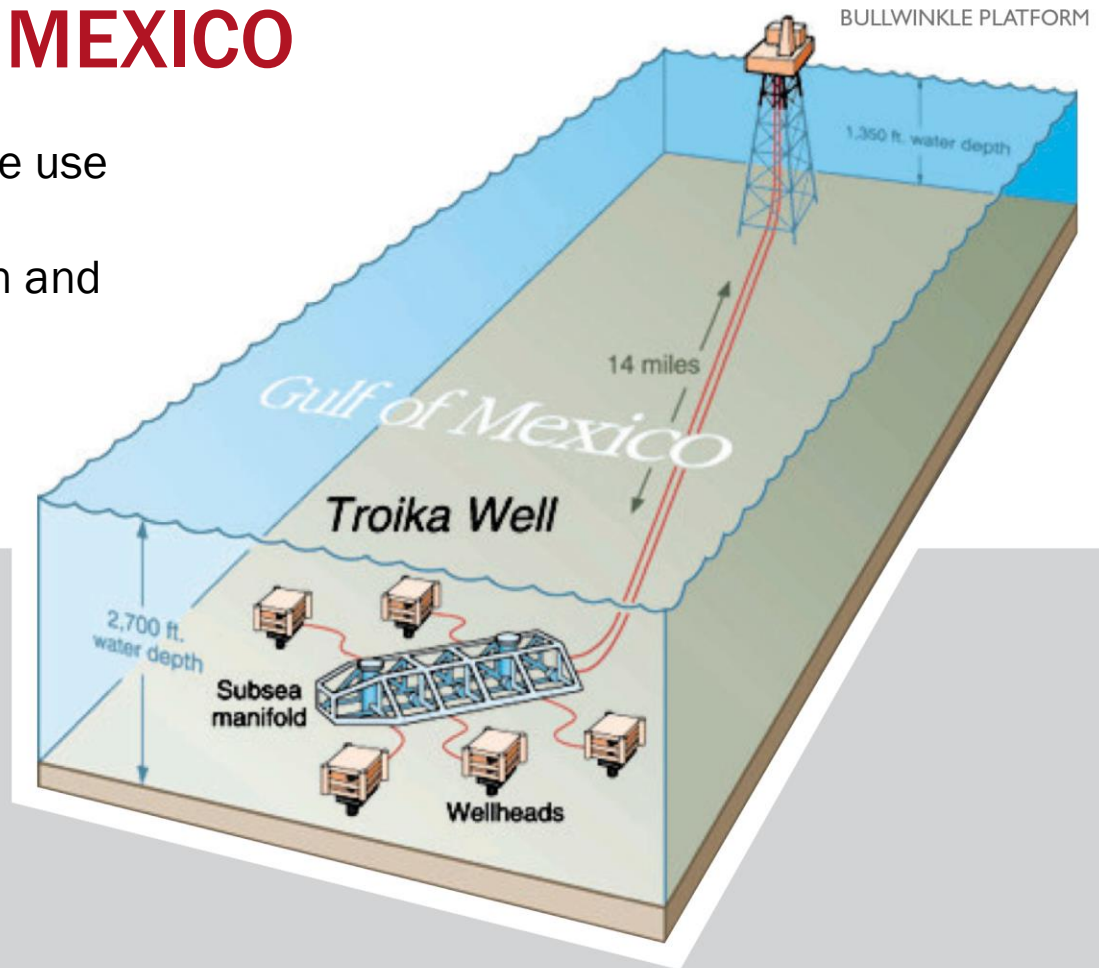


# INSTRUMENTATION OF NASA'S ROBONAUT HAND



# TROIKA – GULF OF MEXICO

ASTRO TECHNOLOGY pioneered the use of fiber-optic sensors on a subsea pipeline to monitor pressure, strain and vibration in external casing pipe bundle during fabrication.



## BASS LITE – DEVIL’S TOWER



- Located in Atwater Valley Block 426
- Utilizes 20.3-cm (8-in) diameter flowline
- 90-km (56-mi) length
- Ties to Devil’s Tower in Mississippi Canyon
- Production — Up to 130 million cubic feet per day
- Water depth — 2,050 m (6,750 feet)
- Commenced operation in February 2008

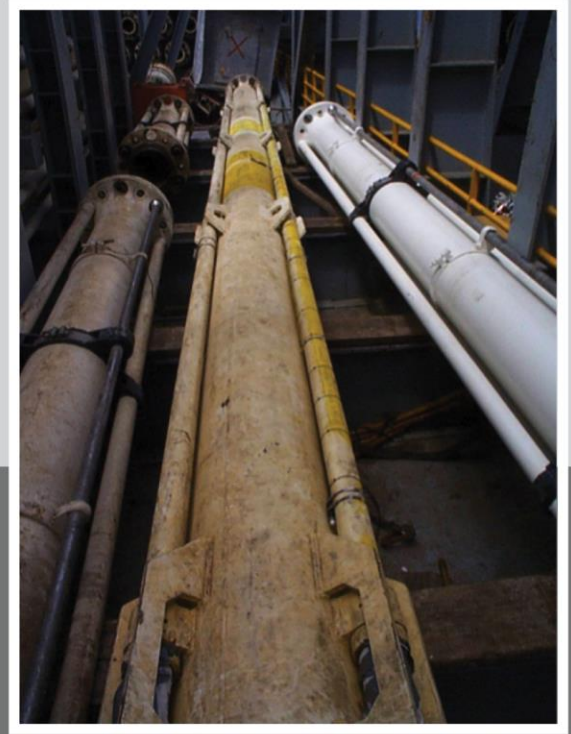
### MONITORING:

- Pressure
- Temperature
- Hoop and Axial Strain

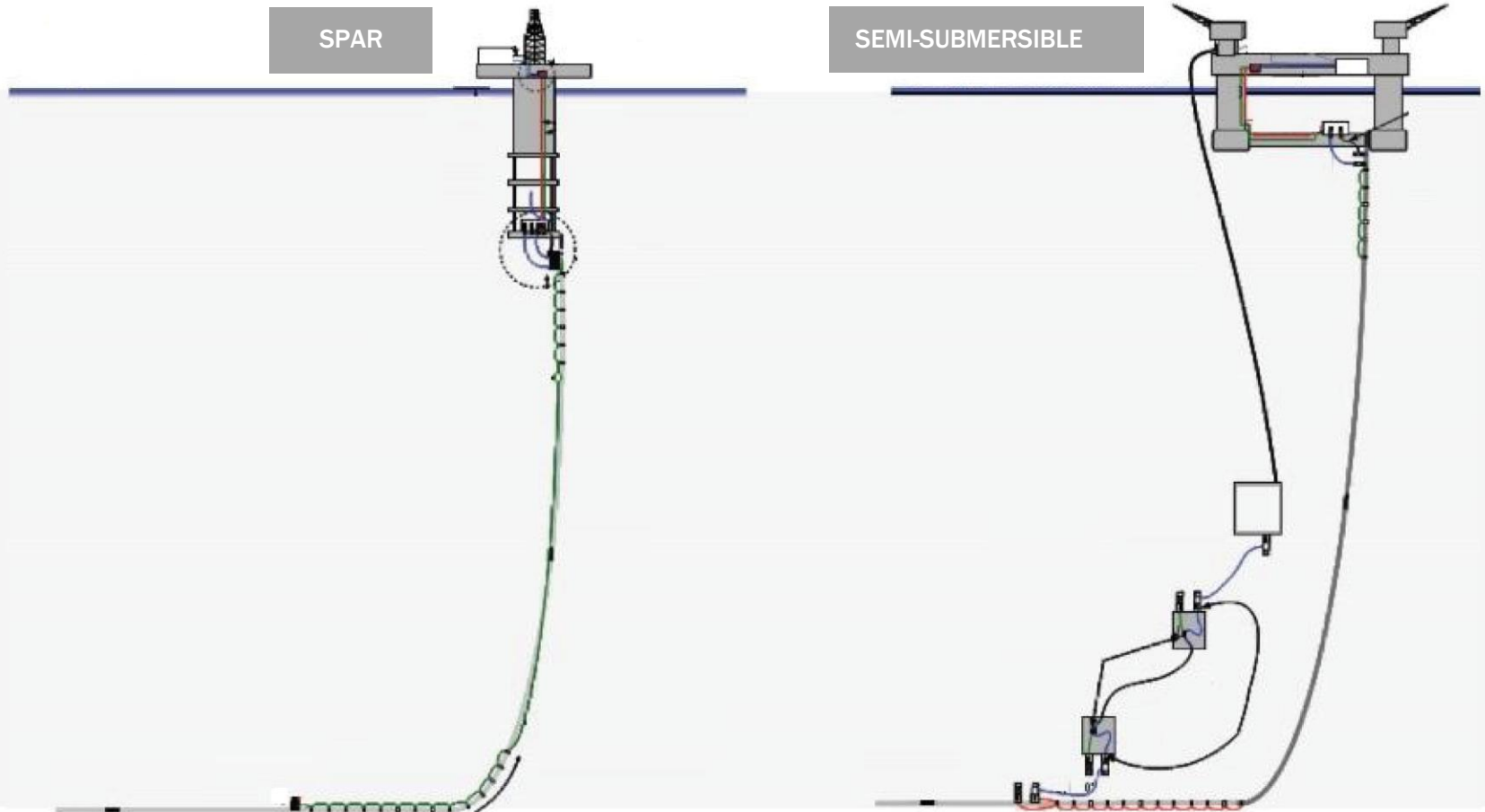


# FIBER-OPTIC SENSORS FOR **DEEPWATER DRILLING**

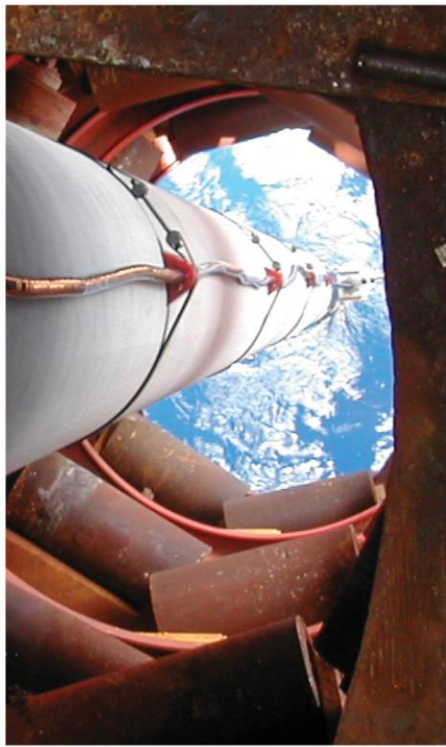
## Ocean Clipper



## PREVIOUS INSTRUMENTATION ON DEEPWATER RISERS



## PREVIOUS INSTRUMENTATION ON RISERS AND FLOWLINES



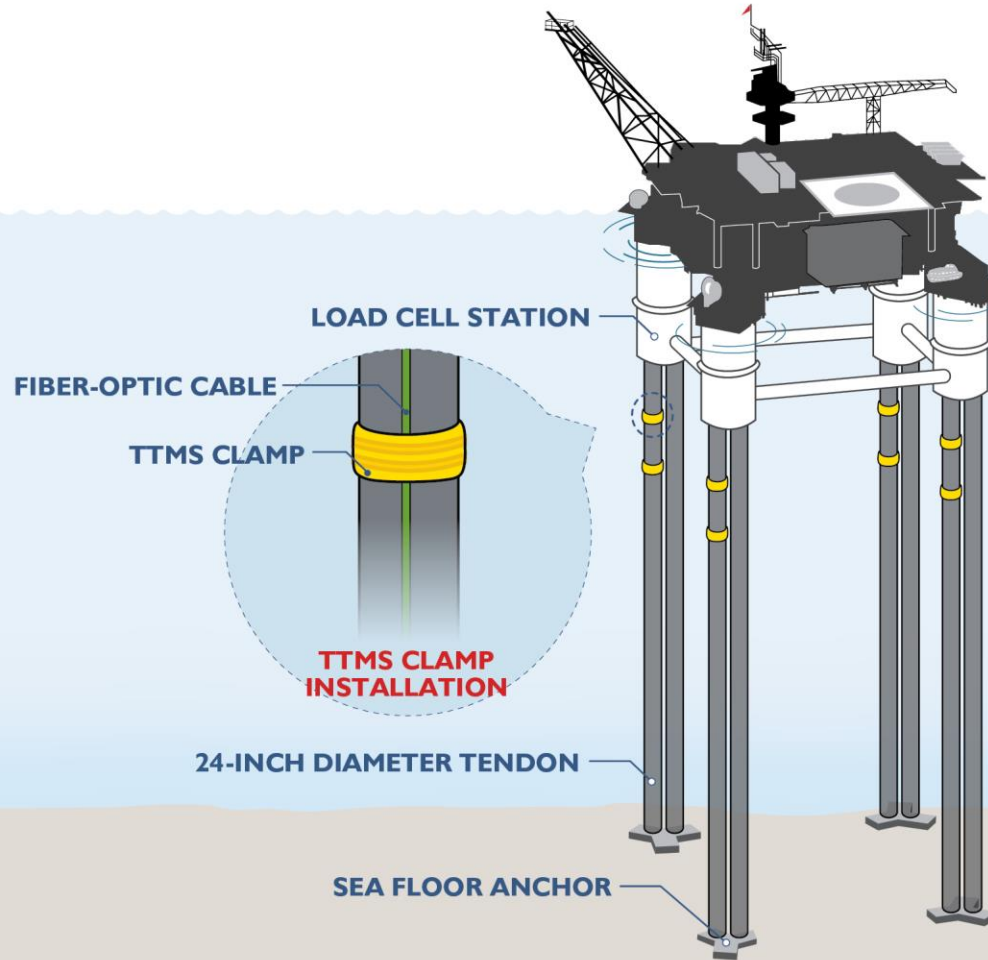


# **NEW** DEVELOPMENTS

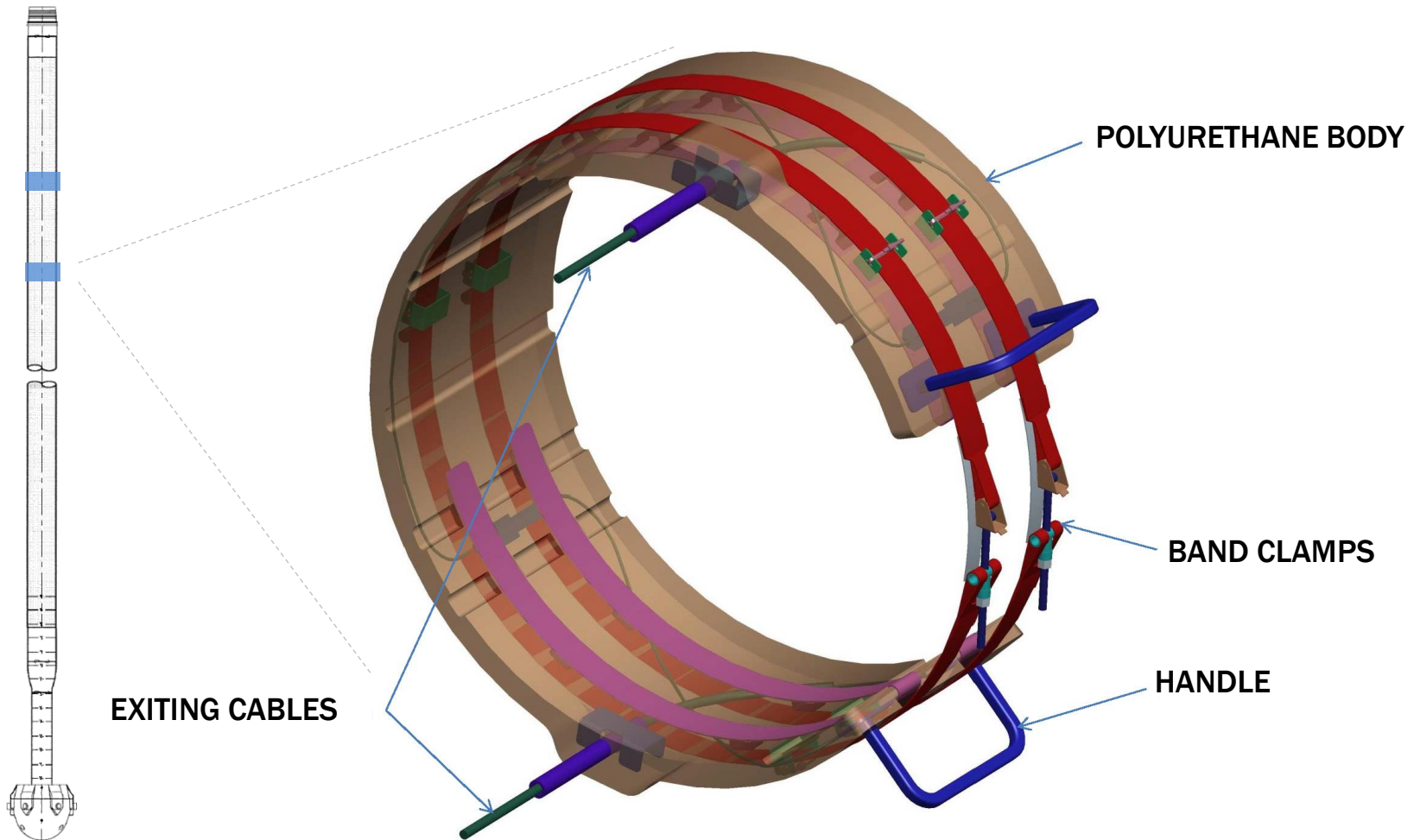
# OVERVIEW OF NEW DEVELOPMENTS

- New tensile strength measurements
- Quantified effects of wet and dry bonding
- Improved clamp design
- Methods for calibration of post-installed sensors

# TENSION LEG MONITORING SYSTEM

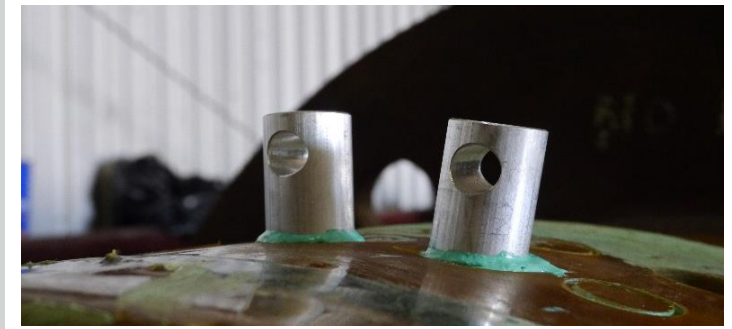
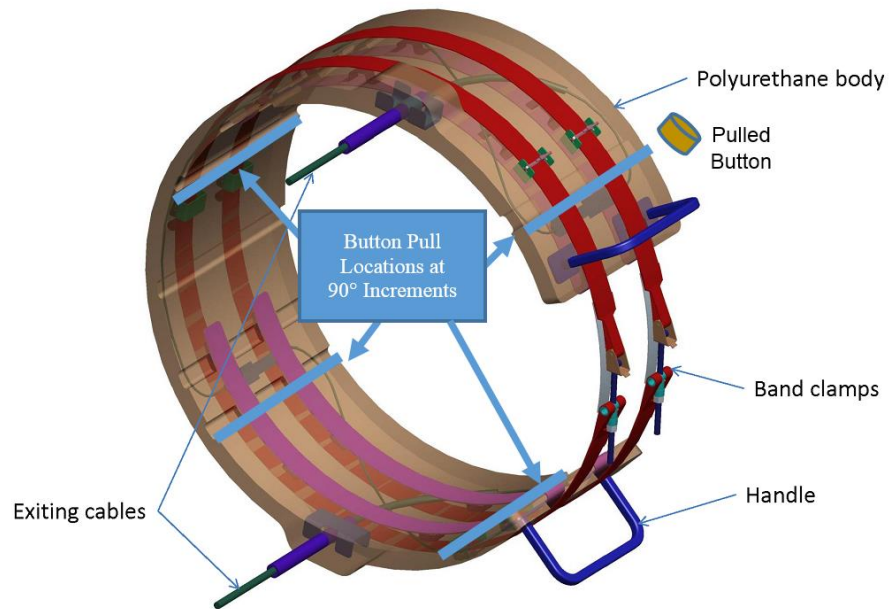


# TTMS CLAMP



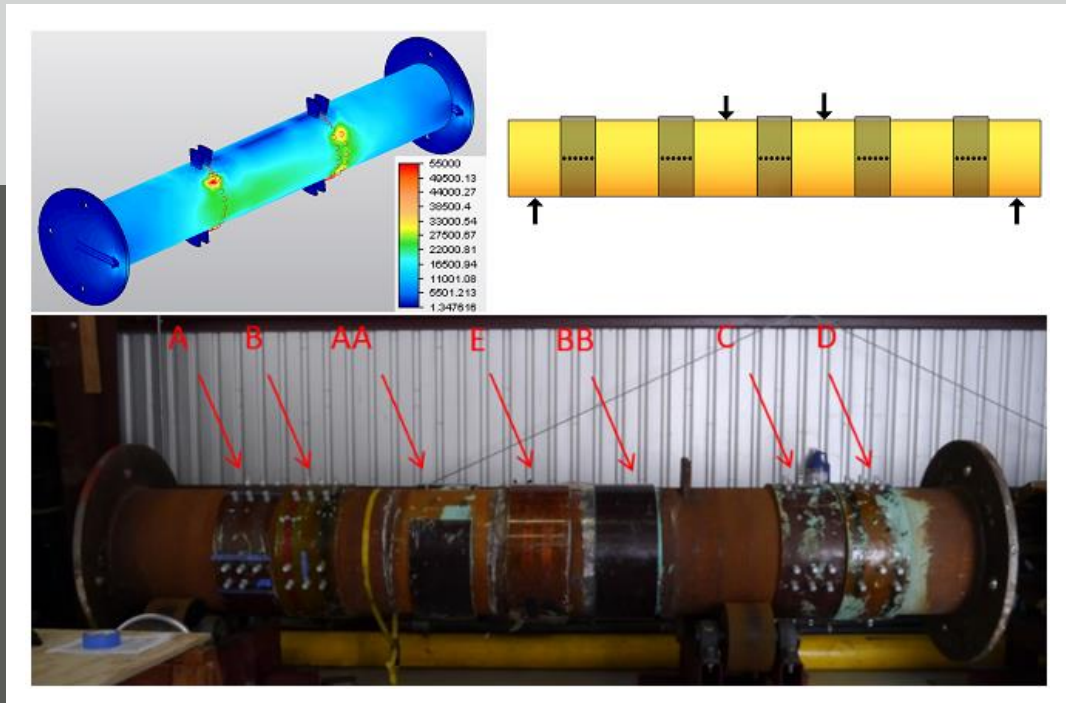
# SUBSEA BONDING STRENGTH **ENSURED**

## Button Pull Testing



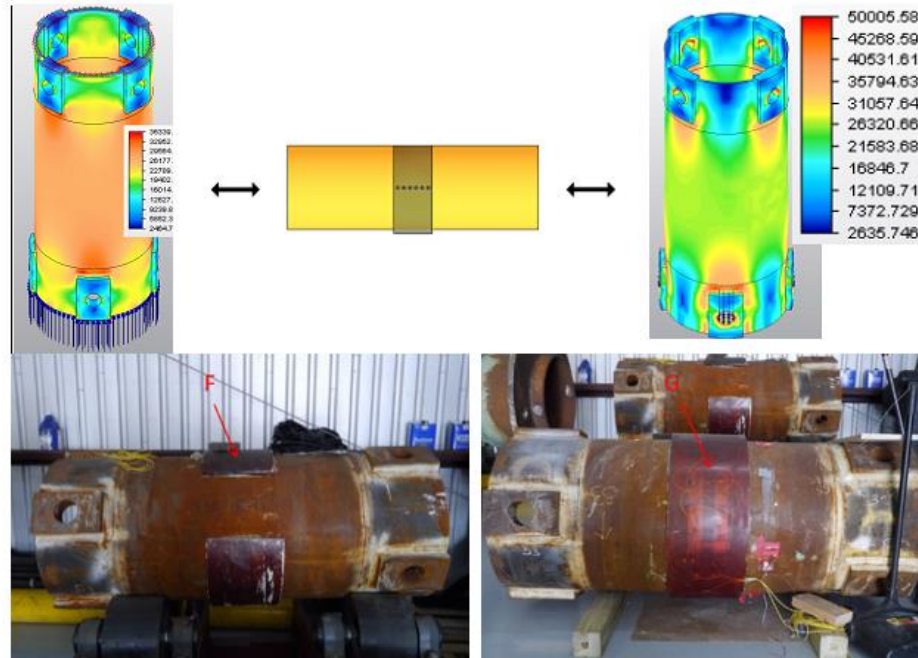
# BONDING MAINTAINED

## Four-Point Bending Test



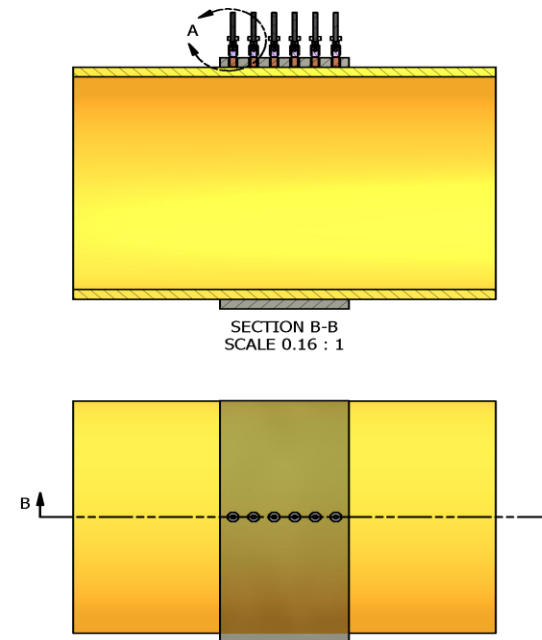
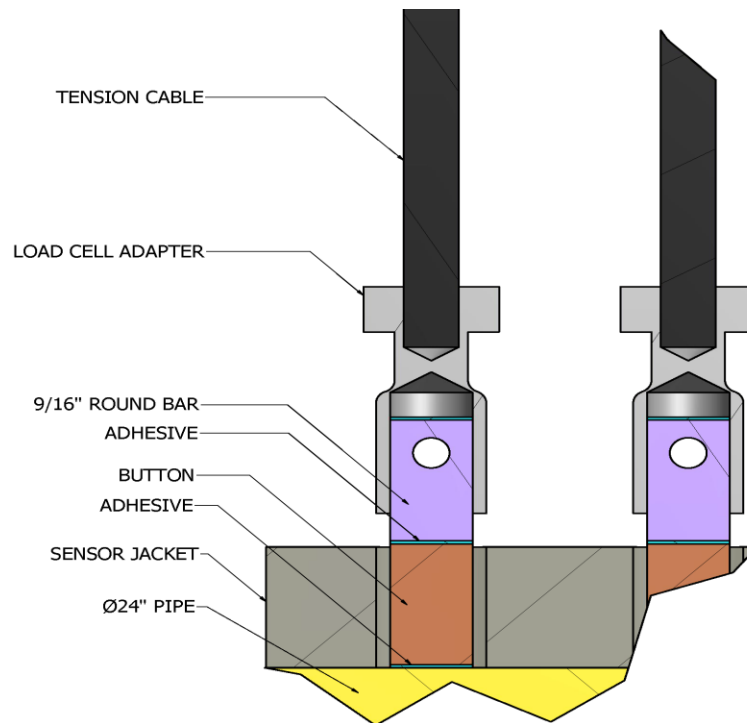
# BONDING MAINTAINED

## Compression and Tension Tests

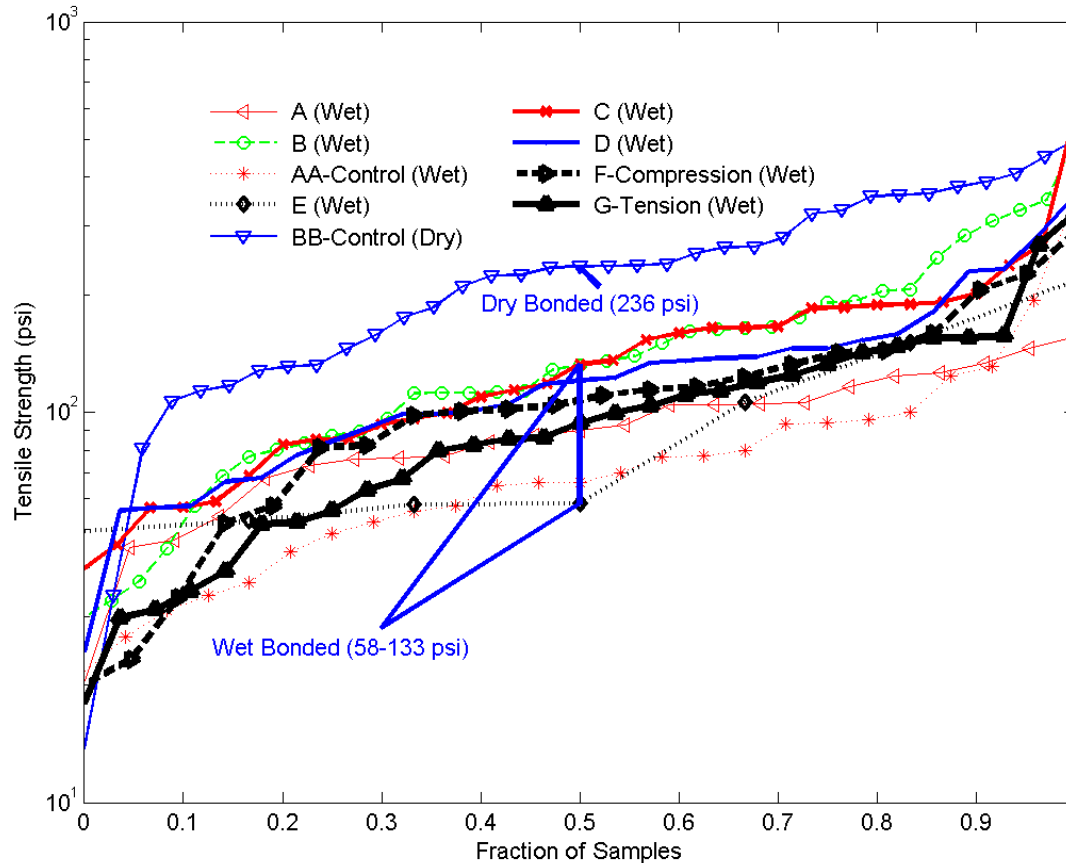


# TENSILE STRENGTH MEASURED

## Button Pull Testing



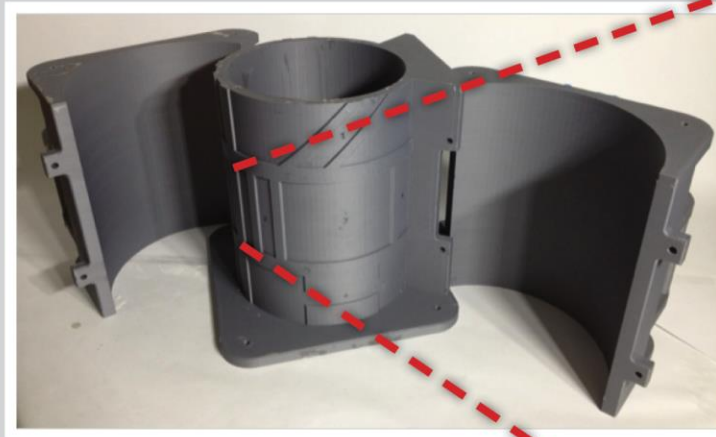
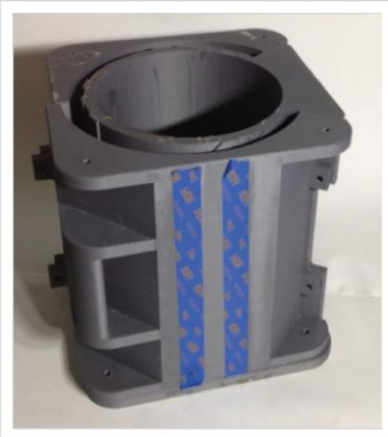
# SUMMARY OF TENSILE STRENGTH RESULTS



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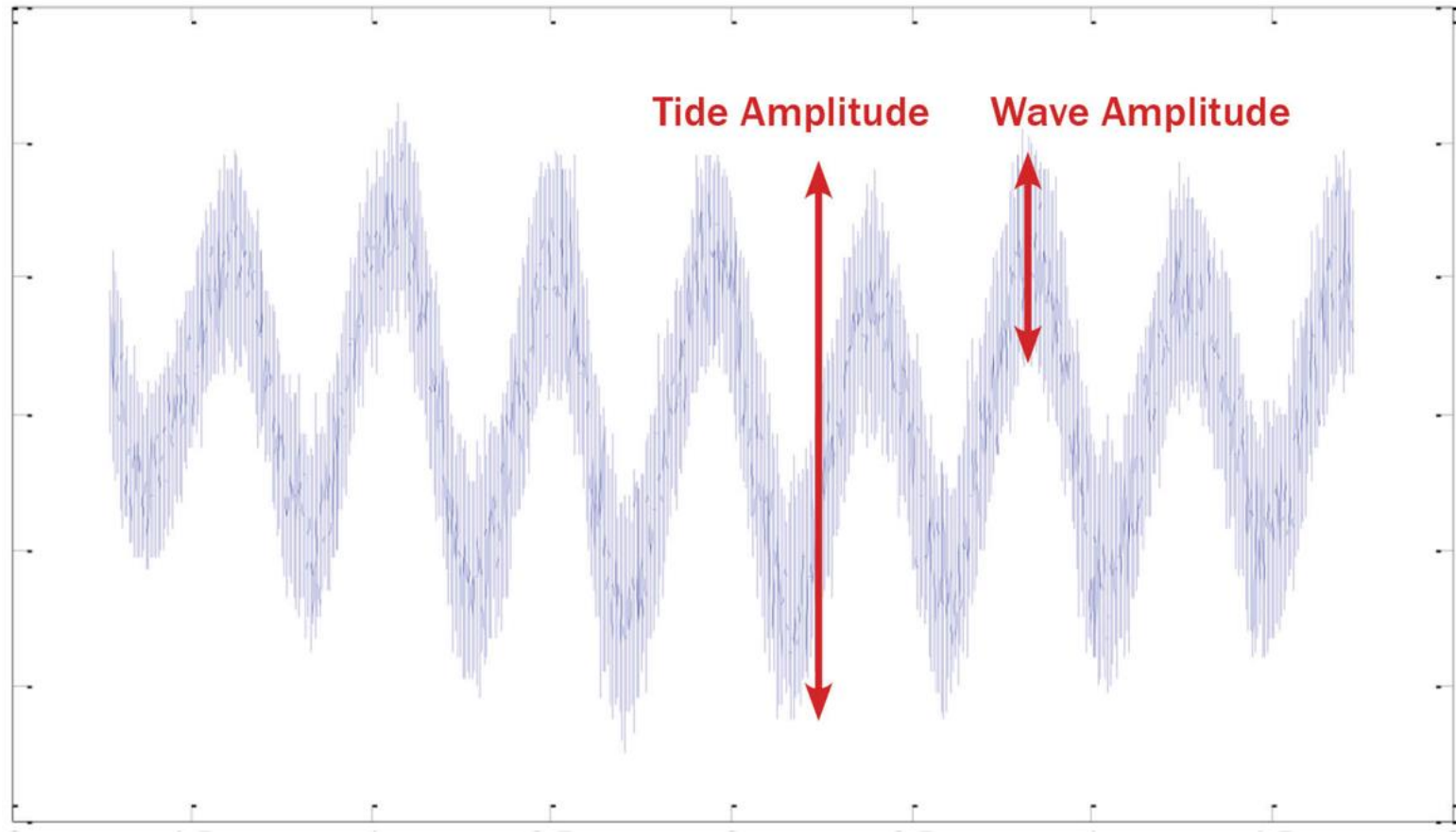
Clamp	Avg (psi)	StDev (psi)	Min (psi)	Max (psi)	Description
<b>BB</b>	<b>292.0</b>	108.9	113.6	498.6	<b>Dry Bonded Control</b>
<b>AA</b>	<b>81.4</b>	47.2	31.1	193.5	<b>Wet Bonded Control</b>
<b>A</b>	94.0	30.4	45.0	155.8	Four Point Bending (Left)
<b>B</b>	174.1	112.4	29.8	503.3	Four Point Bending (Left)
<b>E</b>	<b>91.1</b>	46.9	49.5	150.8	<b>Four Point Bending (Center)</b>
<b>C</b>	142.5	65.6	45.8	267.9	Four Point Bending (Right)
<b>D</b>	136.3	73.6	57.5	358.7	Four Point Bending (Right)
<b>F</b>	<b>114.0</b>	53.7	33.6	225.7	<b>Tension</b>
<b>G</b>	<b>105.3</b>	59.8	29.7	268.8	<b>Compression</b>

## IMPROVED CLAMP DESIGN

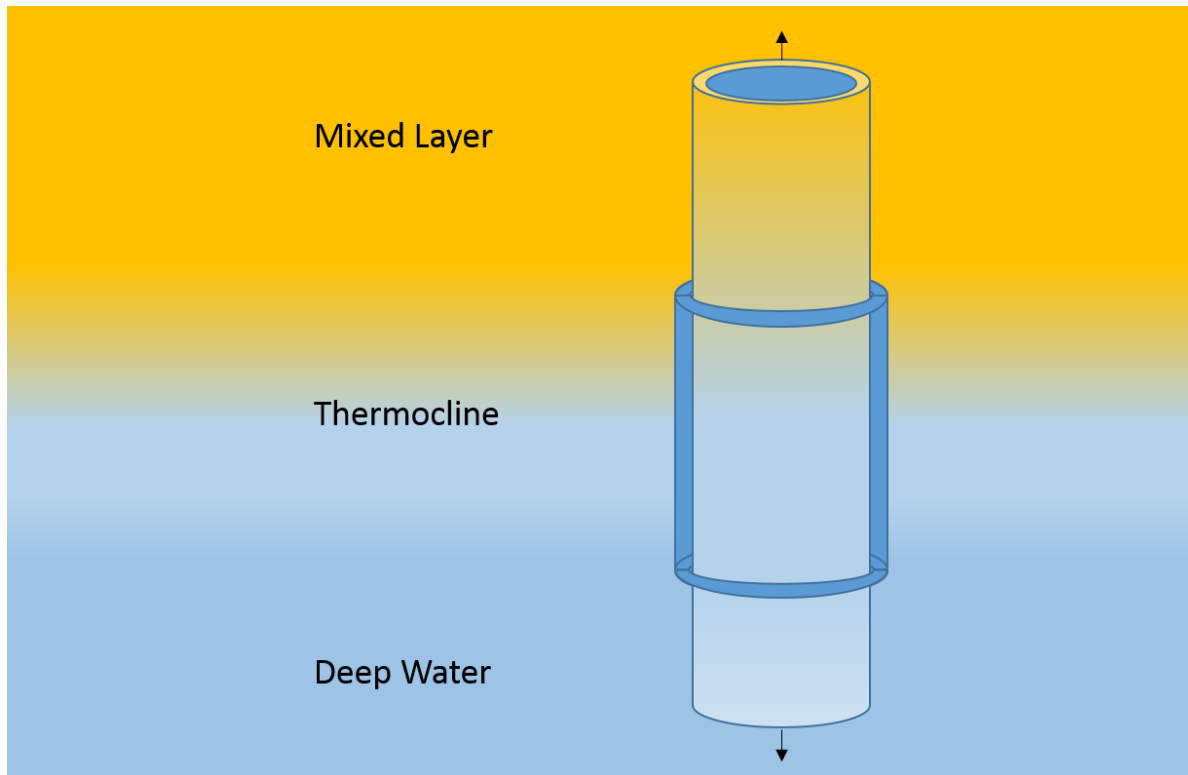


Prototype Clamp Mold Created with 3D Printer

# CALIBRATION OF POST-INSTALLED SENSORS

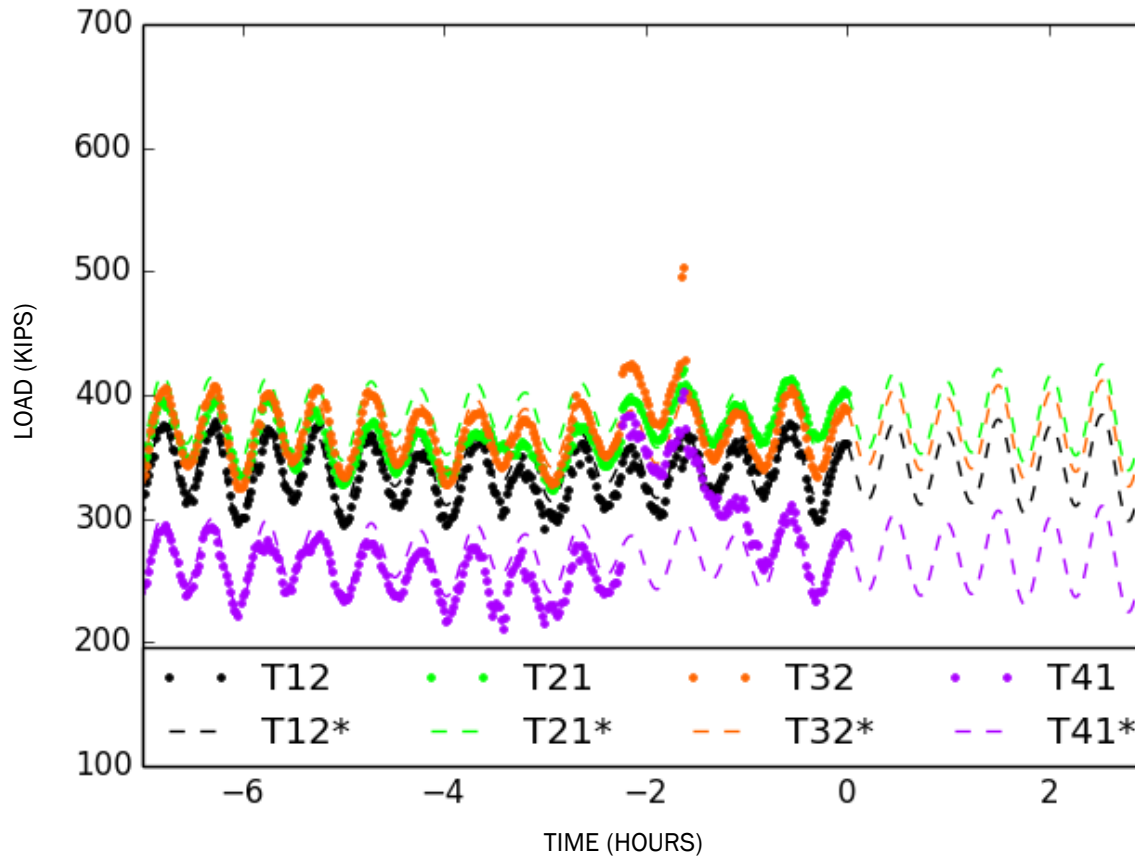


# THERMOCLINE AT **SENSOR CLAMP** DEPTH



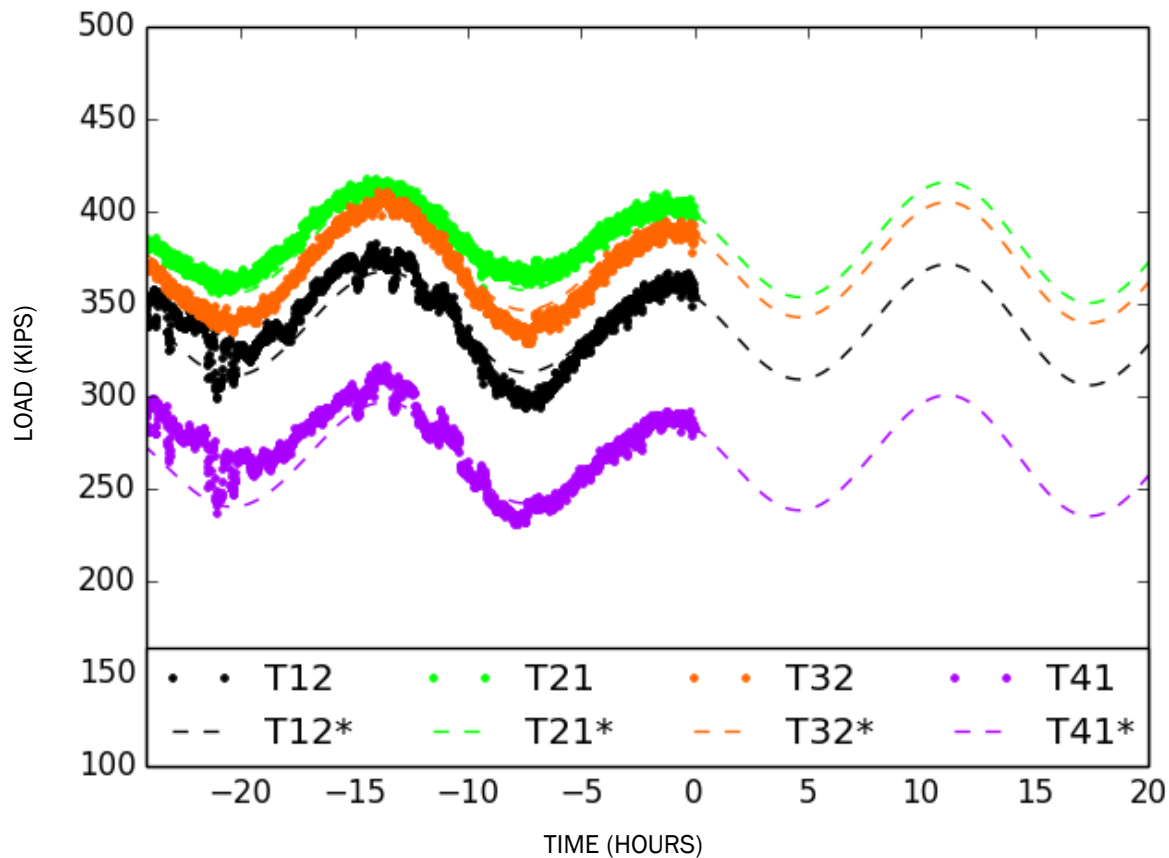
# PREDICTIVE MONITORING

## Foxtrot TTMS Average Load



# PREDICTIVE MONITORING

## Foxtrot TTMS Average Load



# CLEAR GULF

**A COLLABORATION BETWEEN**  
the Oil and Gas Industry,  
NASA and Astro Technology

**ExxonMobil**

**Apache**  
CORPORATION

**ConocoPhillips**

**bhpbilliton**

**Chevron**

**BR**  
PETROBRAS

**HESS**

**woodside**

**Anadarko**  
Petroleum Corporation

**MarathonOil**

**PEMEX**



**Eni**



**TOTAL**

**Statoil**

**PROPOSED PARTNERS**

- Create cutting-edge techniques for managing production
- Develop safer and more environmentally sensitive systems for drilling and production
- Respond to challenges faced when working in remote and harsh environments
- Focus on monitoring assets including platforms, risers, flowlines, subsea equipment, deepwater wells and downhole operations